FINAL REPORT

to

NATIONAL SCIENCE FOUNDATION

Research Initiation Grant: GK-3446

FLUID FLOW IN A THIN RECTANGULAR CHANNEL

by

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SUMMARY

Due to the poor performance of a purchased laser velocimeter, the research project required construction of a laser velocimeter employing self-aligning optics. A flow loop containing a rectangular channel test section of dimensions 3/4 inch by 2-1/2 inches was constructed for making flow measurements. A highly successful instrument package for analyzing signals from laser velocimeters was designed, assembled, and tested. Velocity measurements in the flow channel are being made. In addition, techniques are being developed to define the volume over which flow is measured for different designs of laser velocimeters.

DISCUSSION OF THE RESEARCH

Experiments have demonstrated the feasibility of using continuous wave laser light for measuring local velocities in liquid and gas flows. The principle of operation is optical heterodyning laser light scattered from scattering centers in the moving fluid with a portion of the incident laser beam to produce a beat signal at the frequency of the Doppler shift due to the fluid motion. In water flows the laser light is scattered off 0.5 micron diameter polystyrene spheres dilutely suspended in the water.

In order to exploit the research capabilities of laser velocimeters, the following multi-phase research program was proposed:

Phase I. Development of a laser velocimeter and readout system for turbulence studies.

Phase II. Ascertain as complete an understanding as possible of the capabilities of the laser velocimeter.

Phase III. Construct a flow loop employing a thin rectangular channel flow geometry.

Phase IV. Map the rectangular channel local mean velocities as a function of total flow rate and lateral, transverse, and axial position.

The remainder of this report is a discussion of the research program supported by the National Science Foundation Research Initiation Grant (GK-3446), Fluid Flow in a Thin Rectangular Channel.

As documented in previous correspondence, the research program encountered a major obstacle in its early stages. This was the failure of a laser velocimeter purchased commercially with institutional funds to measure fluid flow over an acceptably small volume. After a considerable effort, it was concluded that modification of this instrument would not prove satisfactory and a new design approach would be necessary.

After a review of possible methods for building laser velocimeters, it was concluded that the self-aligning optics approach suggested by Brayton of ARO, Inc. would lead to an instrument which would measure fluid flow over a smaller volume than could be achieved by alternative approaches. As a consequence, a laser velocimeter was built employing the optical configuration shown in Figure 1. Special coatings were employed on the front and back surfaces of the beam splitter so that equal intensity parallel beams impinge upon the focussing lens. Since the volume over which fluid flow is measured becomes smaller as the focal length of the focussing lens is reduced, a variety of lenses with different focal lengths are employed as the focussing element so that the shortest possible focal length can be used with a given measurement. The optics shown in Figure 1 are mounted on a movable bed so that velocity profiles can be taken across a flow channel.

Two flow loops containing rectangular channel test sections were constructed during the course of the research program. One test section has a flow cross section of 0.1 inch by 3 inches and the other a flow cross section of 3/4 inch by 2-1/2 inches. It is impossible to take meaningful velocity profile data in the 0.1 inch by 3 inch test section because spreading of the laser beams by the glass side walls of the test section caused the volume over which flow is measured to be too large for

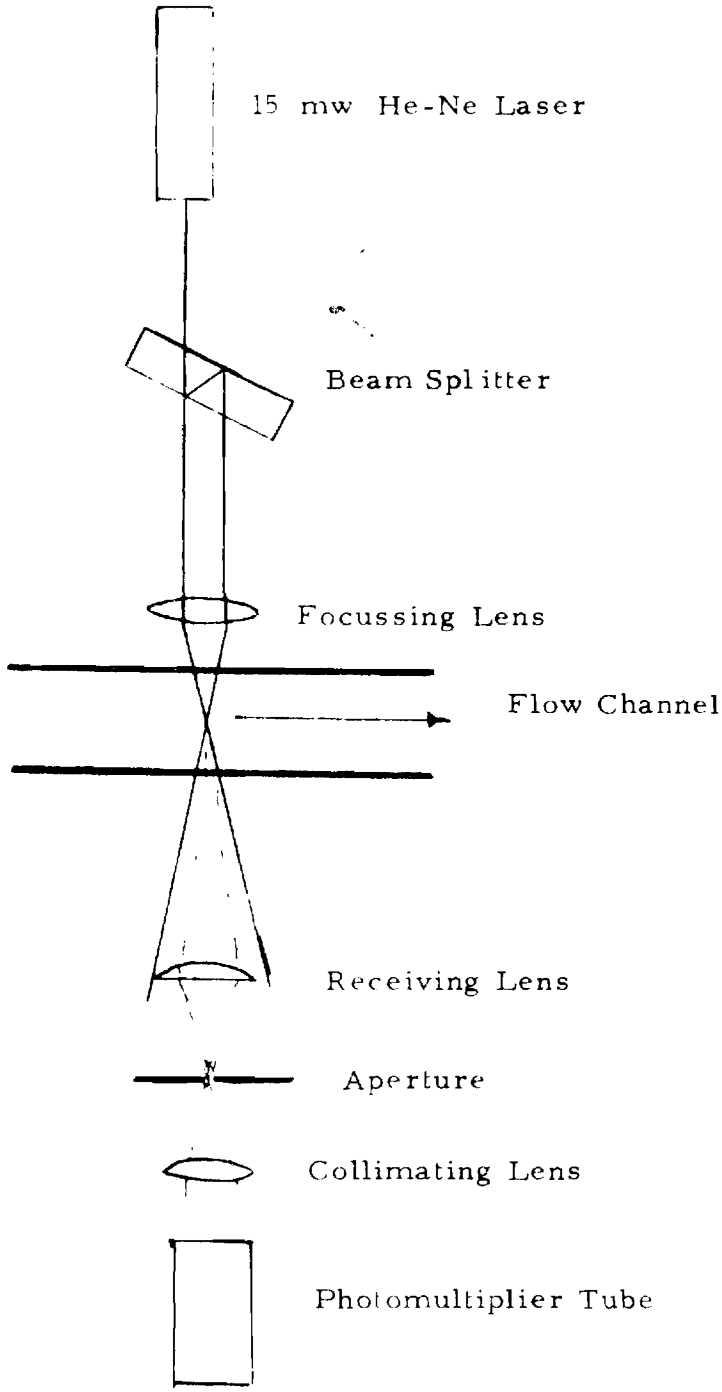

Fig. 1 Dual Beam Laser Velocimeter With Self-Aligning Optics

adequate spatial resolution. In the near future we expect to take velocity profile data in the larger test section. A determination yet to be made is the optimum concentration of polystyrene spheres used as scattering centers in the fluid.

Another phase of the proposed research program was to design and construct a readout system for analyzing signals produced by laser velocimeters. The approach originally suggested was to use a PDP-8 digital computer for on-line data analysis. Because of the difficulties encountered with the commercial laser velocimeter, the equipment funds for the readout system had to be diverted for use in constructing a new laser velocimeter. As a consequence, an analog readout system was developed using existing electronic instruments of the School of Nuclear Engineering.

Figure 2 illustrates the analog instrument package used for analyzing signals from laser velocimeters. A brief description of the operation of this package is as follows: The output signal from the photomultiplier tube approximates a sine wave of variable frequency and amplitude. Flow velocity is proportional to the signal frequency and, consequently, this is the quantity to be measured. The photomultiplier tube signal is fed to a fast discriminator and the signal converted to a train of pulses whose spacing is proportional to the period of the input signal. A time-to-amplitude converter analyzes the pulse train and generates pulses whose amplitude is proportional to the time between two consecutive pulses from the fast discriminator. A multichannel analyzer is used to measure amplitudes of the pulses from the time-to-amplitude converter and store these data in a magnetic core. Data

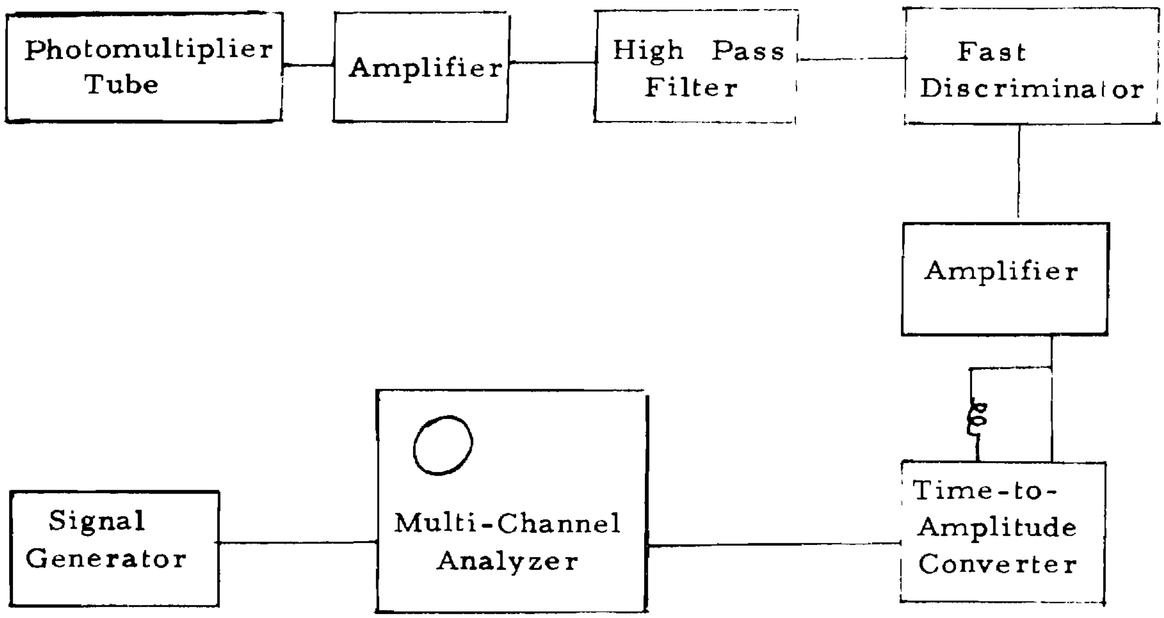

Fig. 2 Analog Readout System For Laser Velocimeters

stored in the multichannel analyzer can be used to determine mean velocities, velocity distribution functions, and the mean square of velocity fluctuations. The readout system performs very well and it is thought that this is the best system proposed to date for analyzing output signals from laser velocimeters.

The readout system functions as an analog-to-digital converter. As a consequence, a logical extension of the research program is to use the system in conjunction with a PDP-8 digital computer for doing on-line data analysis.

This summer velocity profile data will be obtained for the 3/4 inch by 2-1/2 inch flow channel. In addition, an effort will be made toward developing techniques for measuring the volume over which flow is measured in three different types of laser velocimeters.

REFERENCES

1. Brayton, D., Le nnert, A., et al., "Laser Applications for Flow Field Diagnostics," Laser Journal, 2, No. 2, 19-27, March-April, 1970.

Grant Activities

A. Papers

At this time, no papers have been published on the activities supported by the grant. However, a paper describing the readout system will be submitted to the Review of Scientific Instruments this summer. Upon publication of this paper, two reprint copies will be sent to the Division of Engineering.

B. Personnel

James H. Rust, Associate Professor of Nuclear Engineering

Sonny Chafin, Graduate Research Assistant

Tom Willis, Graduate Research Assistant

Wilem Van der Zalm, Graduate Research Assistant

Melvin Bost, Graduate Research Assistant

C. Related Activities of Interest to the Foundation

In the course of this research program it was concluded that very little is known about the capabilities of laser velocimeters. Consequently, we are developing techniques for measuring the volume over which flow is measured in both air and flow channels with glass side-walls.